NASA TECH BRIEF

Lewis Research Center

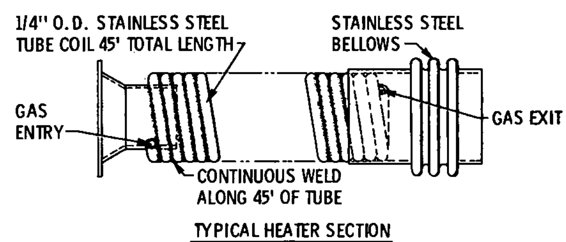
Electrical Gas Heater with Large Flow Range Capability

The Problem:

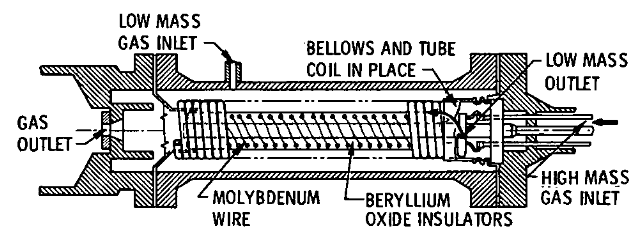
To design an electrical resistance heater for gaseous hydrogen, capable of continuous operation at 1089 K (1500°F) with a "turn-down" ratio greater than 100. The turn-down ratio is the ratio of maximum to minimum mass flow rate the heater can handle at fixed inlet gas pressure and outlet temperature. Conventional heater designs, of fixed geometry, are limited by pressure drop at high flow rates, and by allowable element temperature and minimum flow velocity at low mass flow rates. Conventional heater designs have turn-down ratios of 25 or less.

The Solution:

To provide a hydrogen heater with a turn-down ratio greater than 100, an auxiliary heat transfer device in the form of a tightly-wound helical tube was incorporated into a conventional heater design. This device greatly increases the low flow rate capacity of the heater by providing maximum heat-transfer area for low mass flows. The auxiliary device is heated by radiation from the primary resistance element, thereby eliminating the low mass flow limit imposed by the minimum allowable velocity over the primary heating element.



TYPICAL HEATER SECTION



MODIFIED HYDROGEN HEATER

How It's Done:

As shown in the figure, the gas heater is powered by an electrical resistance heated core of molybdenum wire, helically wound in a dense array supported by beryllia insulators. The insulating strips of beryllia are evenly spaced on the molybdenum support rod and have accurately located holes to support and position the resistance wire. There are three discrete circuits or legs to the heater, all wound through the same insulators in alternating holes. The wire is 0.157 cm (0.062 in) in diameter, 13.7 m (45 ft) long, and has a cold resistance of 0.59 ohms per leg. Concentric with the heater core is the auxiliary heat exchange device. It consists of 13.7 m (45 ft) of 0.64 cm (0.25 in) diameter stainless steel tubing of 0.051 cm (0.020 in) wall thickness. The stainless steel tube is wound over a mandrel to form a helical cylinder in the same manner as a coil spring. The seam between adjacent coils of tube is welded along the entire tube length to form a sealed cylinder. For low mass-flow rates, the incoming gas flows through the heat exchanger and then past the heating elements before exiting. For the high mass-flow rates, the gas is valved so that it flows directly over the heating elements and exits. Heat transfer in this arrangement is by direct convection between the flowing gas and the wire core. A continuous range of mass-flow and/or heating rates is obtained by mixing these two modes proportionally. For operation where mass flow demand is very small, essentially all the heat transfer takes place in the auxiliary tube coil where convection coefficients are relatively high and the core velocity is extremely low. The tube coil is heated by radiation from the molybdenum wire and surrounding hot support materials. This arrangement greatly increases the turn-down capability of the heater by eliminating the low core velocity limit and the associated problem of non-uniform element temperature caused by natural convection at the low core velocities.

(continued overleaf)

Notes:

1. Although the heater described above was operated over a turn-down range of slightly more than 100, its actual range is significantly greater than 100. The total turn-down ratio of this heater was not determined because of restraints dictated by the test program in which the heater was used.
2. This design concept is applicable to other than hydrogen; however, the choice of molybdenum for resistance wire and support structure is limited to gases which are inert or reducing over the operating temperature range.
3. Further information is available in the following report:

   NASA CR-134523 (N74-16613), Fundamental Study of Transpiration Cooling

   Copies may be obtained at cost from:

   Aerospace Research Applications Center
   Indiana University
   400 East Seventh Street
   Bloomington, Indiana 47401
   Telephone: 812-337-7833
   Reference: B75-10024
4. Specific technical questions may be directed to:

   Technology Utilization Officer
   Lewis Research Center
   21000 Brookpark Road
   Cleveland, Ohio 44135
   Reference: B75-10024

Patent Status:

NASA has decided not to apply for a patent.

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